A STUDY OF THE RELATIONSHIP BETWEEN
DEPTH PERCEPTION OF MOVING OBJECTS
AND SPORTS SKILL

by

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APPROVAL SHEET

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The purposes of this study were (1) to develop a standardized measure of depth perception of moving objects, (2) to determine the relationship between depth perception of moving objects and sports skill, (3) to re-explore the relationship between depth perception of stationary objects and sports skill, and (4) to compare the relative effectiveness of the two methods of measuring depth perception in relating this quality to sports skill.

Subjects were 36 undergraduate physical education majors at the University of North Carolina at Greensboro. Two depth perception instruments were used at distances of 10 feet and 20 feet. One was the Howard-Dolman Apparatus, a traditional measure of depth perception, and the other was an adaption of the Howard-Dolman Apparatus constructed as a new measure of the depth perception of moving objects. The skills tests were the Lockhart-McPherson Badminton Wall Volley Test, the Scott-French Softball Repeated Throws Test, and the Scott-French Revision of the Dyer Wallboard Test.

1. The Howard-Dolman Apparatus at a distance of 20 feet had a low reliability coefficient. The Howard-Dolman Apparatus at a distance of 10 feet and the Adapted Apparatus at both distances proved to be sufficiently reliable.

2. The Adapted Apparatus, which involved moving objects, showed a low relationship to the Howard-Dolman Apparatus at 20 feet. The relationship of .39 was high enough to be significant but not substantial to any great extent.
3. The Howard-Dolman Apparatus showed no relationship to the softball repeated throws, badminton wall volley, or tennis wall volley tests.
4. The Adapted Apparatus showed no relationship to the softball repeated throws, badminton wall volley, or tennis wall volley tests.
5. It was concluded that while the Adapted Apparatus, which involved moving objects, appeared to be a reliable measure it did not appear to be any more accurate a measure than the Howard-Dolman Apparatus. It was shown, however, to require fewer trials to be administered.

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CHAPTER I

INTRODUCTION

It has long been accepted that vision plays a significant role in the individual's ability to succeed in sports; however, as Bannister and Blackburn note

> A 'GOOD EYE' is usually considered to be all important for proficiency at . . . games . . . in which a fast-moving ball has to be hit with speed and precision either by the hand itself or by an instrument held in the hand. But, provided the individual can see, the 'good eye' appears to be quite independent of visual acuity. Many of the best players have an acuity far below normal. In all probability the 'good eye' is not a true eye factor at all. It seems rather to be a very high innate visuo-muscular co-ordination, which enables the one who possesses it to hit the ball with his racket or bat held so that the planes of the face make a particular angle being determined by the way in which the ball is moving, and it enables him to hit the ball in exactly the right position in space and at the correct speed, with the time judged to an extraordinary degree of nicety. As is well known, all this may be accomplished by a man with very poor (uncorrected) visual acuity. (26:382)

This visuo-muscular coordination is commonly referred to as visual perception. It is the retina of the eye which receives the stimuli, but it is the muscles, fundamental and accessory which achieve adjustments for position, distance, size, and form. The whole experience is organized in the brain's cortex. (7:257)

There have been many studies to determine the relationships between visual perception and sports skills; however, as Cratty points out

> Generally, investigations are carried out which compare perceptual-motor activities having highly dissimilar input qualities. For example, a test of static depth perception, involving the slow and deliberate alignment of rods within a tube, is often compared to fencing, basketball, or baseball skill, activities which require the rapid response to objects in space. (5:136)

Thus, it appears that researchers have been involved with descriptions of comparisons of qualities which, according to Cratty, do not correspond.

He further charges that contemporary researchers must make it their task to develop standardized measures of dynamic event perception which more nearly correspond to the real world of moving objects. Cratty feels that comparisons between scores achieved in such tasks to motor performance measures should produce higher perceptual-motor correlations than those obtained thus far. (5:136)

The challenge of developing a standardized measure of the performer's depth perception of moving objects prompted this study. An adaption of the Howard-Dolman Depth Perception Apparatus (1:77-78), a static measure of depth perception, was conceived and constructed. In this adaption, the rods were powered by an electric motor and the subject dealt with two moving objects.

CHAPTER II

STATEMENT OF THE PROBLEM

The purposes of this study were multiple:

1. To develop a standardized measure of depth perception of moving objects.

2. To determine the relationship between depth perception of moving objects and sports skill.

3. To re-explore the relationship between depth perception of stationary objects and sports skill.

4. To compare the relative effectiveness of two pieces of apparatus in relating depth perception to sports skill.

A pilot study was conducted to develop a standardized measure of depth perception of moving objects using the Howard-Dolman Depth Perception Apparatus and an adaption of the Howard-Dolman Apparatus using 30 graduate students enrolled in the University of North Carolina at Greensboro for the Spring Semester 1966. Relationships between both pieces of apparatus and three sports skills were then determined for 36 undergraduate women physical education majors enrolled in the University of North Carolina at Greensboro for the Spring Semester 1966. The sports skills used were the softball throw, forehand and backhand drives in tennis, and badminton volleying ability. In addition, the two methods of measuring depth perception were examined to see if a pattern existed in relating depth perception to sports skill.

LIMITATIONS

The major limiting factor was the variety of elements affecting the individual's perception of depth. One might categorize these factors under the general heading of experience. Through experience, the individual learns the limitations of his ability to perceive depth and compensates for his deviations. Thus, a highly skilled individual may have poor depth perception and have learned to compensate for error through developing other perceptual capacities.

The mechanical problems of administering the Howard-Dolman Apparatus and the Adapted Apparatus might be considered limitations. Though a room light was provided directly above the apparatuses, other lights in the room and the necessity for administering the tests at various times of the day may have had an affect upon the accuracy of the subjects. However, every attempt was made to keep testing conditions within an acceptable range of conformity.

DEFINITIONS

> Accommodations: . . . the faculty of increasing the dioptric power of the lens and . . . the factor that enables the normal eye to focus near objects at less than infinity (. . . 20 feet or 6 meters)

on the retina to form a clear image . . . both monocular and binocular single vision. (1:73-74)

Aerial perspective: . . . the changes with respect to color, brightness and contrast which distant objects undergo on account of variations in the clarity of the intervening atmosphere. (32:657-658)

Binocular parallax: . . . the impression of relief or solidity given to an object by the slightly different view of it which is obtained by the fact that the right eye sees a little more of the right side of the object and the left eye sees a little more of the left side of the object . . . in binocular single vision only. (1:75)

Binocular vision: . . . the simultaneous use of the two eyes. (15:666)

Closure: . . . the tendency for gaps to be perceived as filled in. (15:667)

Convergence: . . . the ability of the two eyes to fix on an object at a distance less than infinity. The closer the object the greater the amount of convergence required for bilateral fixation. Failure of convergence causes a blurring of vision or a pathological diplopia with a resultant decrease in depth perception . . . operates with binocular single vision only. (1:74)

Depth perception: . . . the ability to appreciate or discriminate the third dimension, to judge distance, and to orient oneself in relation to other objects within the visual field. (1:71)

Empty depth: One surface in front of another. (29:51)

Figure-ground perception: Perception of objects or events as standing out clearly from a background. (15:672)

Filled depth: The slant or recession of a surface. (29:51)

Interposition: . . . a near object overlaps and partly blocks out portions of objects farther away. (5:122)

Inter-pupillary distance: The distance between the eyes. (26:383)

Kinesthesis: The . . . conscious experience of the muscles. (14:609)

Linear perspective: The tendency of parallel lines to converge as they extend away from the observer . . . . (5:123)

Monocular vision: Vision involving . . . the use of only one eye. (15:282)

Motion parallax: . . . the apparent differences in speed at which various objects, varying distances from the observer seem to be moving relative to him and to each other. It refers also to the change in an object's shape which seems to take place as an observer moves around to inspect a complex figure from several positions. (5:129)

Perception: . . . the process of discriminating among stimuli and of interpreting their meanings. It intervenes between sensory processes, on the one hand, and behavior, on the other. Being an intervening process, it is not directly observable. It can be investigated and understood only by observing responses made to stimuli under various conditions. (15:299)

Perceptual flexibility: . . . the willingness to proceed from one fixed concept or form to a second. . . . the individual, while accurately perceiving a given structure or object, is able to imagine it in a variety of positions. (5:96)

Perceptual pooling: . . . the tendency to form judgments by continual reference to the average of past experiences about similar objects . . . . (5:122)

Perceptual selection: . . . the manner in which we select central objects from their backgrounds and our relative dependency upon the central figure, or its surroundings, when making perceptual judgments. (5:94)

Perceptual speed: . . . the speed with which perceptual judgments are made and acted upon. (5:96)

Perceptual structuring: . . . the ability to effectively structure a task, synthesize a form, or organize a situation despite the presence of illusions and distractions or the presence of other types of conflicting forms, activities, or objects . . . also refers to the ability to draw whole meanings from fragmented evidence and to differentiate accurately between various kinds of objects and situations. (5:97)

Physiologic diplopia: . . . the ability to recognize differences in distance between two objects in the field based on the fact that all objects in the field closer or farther away than the object fixed gives rise to diplopia or double vision . (1:72)

Proximity: . . . principle in the perception of two-dimensional space . . . objects which are adjacent and placed next to each other will generally be integrated into patterned wholes. The closer objects are placed . . . the more likely they will be combined into a common meaning or figure. (5:121)

Radial motion: . . . motion whose apparent direction is directly toward or away from the observer. (9:71)

Receptor: . . . a cell that is specialized to respond to relatively small change of a particular kind of energy. (15:301)

Retina: The photosensitive layer of the eye on which images of objects are projected. It contains receptors, known as rods and cones, and nerve cells that convey impulses to the brain. (15:687)

Space perception: . . . the perception . . . of objects in their spatial (geometrical) relations to each other and the observer. (6:209)

Stereoscopy: Binocular parallax.

Tangential movement: Motion whose apparent direction is at a constant radial distance from the observer. (34:394)

<u>Terrestial</u> <u>association</u>: An acquired characteristic utilizing linear perspective, overlapping contours, light reflections, and shadows in the judgment of distance. (1:76)

CHAPTER III

REVIEW OF LITERATURE

One must first understand the perceptual process as a whole before understanding depth perception and its relationship to sports skill. Perception is not synonymous with sensation. Perception is the more inclusive term and is the final product derived from the bombardment of the nervous system with many different types of stimuli. The perception is distinctive within itself. (9:76) It may be viewed as an intervening process between the senses and observable behavior. Of itself, perception is not observable and information may be gained about the perceptual process only by observing how a subject responds to stimuli under varied and controlled conditions. (15:299)

Man's conception of perception has taken many turns; yet, certain basic facts are accepted by all. The primary and the most limiting factor of perception is sensory discrimination. (15:300) Beyond this, perception becomes, at once, a

> . . . dynamic process of attaching meaning to objects, events, or situations occurring within the spatial and temporal proximity of the individual. It is a process involving organizing, feeling, change, and selecting among the complexity of events with which humans are continually confronted. It involves the attention-set, an object

> sensory stimulation, and interpretations
> with the resultant decision. (5:99)

It is an adjustive factor which initiates, regulates, and determines the effectiveness of homeostatic mechanisms giving the human organism cues to how successful or unsuccessful performance patterns are. (20:335)

Because stimuli orginate outside of man, in his environment, perception is influenced by the conditions of the environment at the time stimuli are presented. No two men live in exactly the same environment; thus, all of humanity is subject to varying degrees of subjective distortion through perception of the original stimuli presented. (4:441; 31: 35-46). Further, what one perceives from his environment and his reaction to his perceptions might be considered as a guess based upon previous experience coupled with a certain sense of probability. (10:444)

The first systematic formulation of the problem of perception came from Berkeley in 1709. Unlike earlier theorists who saw perceptions as a process of reception, Berkeley tried to show that perception is a habit evolved from the addition of memories to presently given sensory experience (4:447-448)

Later psychologists continued to be interested in the process of perception. Thomas Reid of the Scottish School of the 18th Century emphasized the self-evident in nature as that which is perceived. (21:192) Helmholtz stressed unconscious inference in perception, bringing into play the experience factor. (21:238) Wundt developed a theory of apperception or the bringing of sensation and pre-existing ideas into a unity, sensation being an external factor and ideation an internal factor. (21:255) These early modern psychologists evolved their divergent theories from a basic theory of a one-to-one relationship between stimuli and perception (5:81)

Advocates of the core-context theory, E. B. Titchner (19), Edwin Boring (3), Harry Helson (8), and R. S. Woodworth (23), hold that perception has an immediate core of sensations which is relatively the same from one individual to another. Secondary sensations from past experience make up a learned context which becomes the variable from individual to individual. (5:81-82)

The transactionalist viewpoint was introduced by Adelbert Ames. Others who have developed upon it most notably are Ittelson (9) and Kilpatrick. (10:432-444; 34:394-402) Essentially, the theory proposes that perception evolves from sensation through the individual's psychological structuring of the events and objects involved. (23:52; 5:85-86)

Perhaps Gestalt psychology has been the most influential statement of perceptual theory in this century. "The word Gestalt means form or shape, and, more generally, a manner or essence." (5:82) Gestalt theory is based upon the existence of wholes. The behavior of these wholes is intrinsic in nature and is not determined by their individual elements. (22:2) These psychologists see complex perceptions as ". . . the result of an inherent relationship between properties of the thing perceived and the properties of the brain." (10:433) This theory still exerts a positive influence upon the field of perception; however, it is now recognized as having shortcomings, one of which is a defective treatment of whole and part relationships. (23:245)

The socio-cultural theory is actually an approach to perception taken by psychologists from several schools of thought. In general, the theory places emphasis upon a social and cultural basis. Studies like that of Allport and Pettigrew (25) which describe the cultural influence upon a trapezoidal illusion of movement among Zulus are examples of experimental development from this theory. From the broad base of the socio-cultural theory, one may derive perceptual implications involved with any of the other bodies of theory in existence today. (5:86-88)

Werner and Wapner (38) are advocates of the newest theoretical approach to perception. They base this theory upon the works of physiologists such as Sherrington (17), Magnus (12), Stein (18), and Metzger (35) who have shown a relationship between sensory stimulation and muscular tonus. (37) They refer to this theory as the sensory-tonic field theory of perception. The concept means that there is a field of two parts. The body and the object are these psychophysical parts. Perception of the object depends upon the way in which the stimuli from this object affect the organism and also upon the subsequent reaction of the organism to the stimuli.

The stimuli do not necessarily impede the present organismic state; however, if they do interfere, or are not compatible with the organismic state, the organism will adjust itself in order to establish an equilibrium between body and object.

Werner and Wapner believe that the ". . . perceived properties of the object are a mirror of these dynamic relations between the object stimuli and ensuing body activity." (38:325)

While each of these perceptual theories will give insight into the problem of perception, it is difficult, if not impossible to choose only one as a frame of reference. Rather, for the purposes of this study, one must be only cognizant of these theories.

Essentially, the perceptual process is involved with the development of four components--perceptual structuring, perceptual speed, perceptual selection, and perceptual flexibility. The process begins as stimuli are received by receptors. The receptors act as analyzers picking some stimuli to react to more than to others. These receptors then send signals upstream through the nervous system to the brain. Of course, many of these receptors are hooked up together and they are all sending signals at the same time. The nervous system must sort out the signals before perceiving their meaning. (15:301; 16:3015)

The process might be considered as having five steps. First, there is a preparatory set within the perceiver prior to the presence of stimuli. This set depends upon a "pooling" of the individual's past experience, his cultural environment, and his muscular-skeletal and visceral tonus. For the most part, the individual is unaware of these factors and their operation.

Second, the object or event enters into a spatial and temporal proximity to the organism becoming a distinct identity located in time and space. The third step comes when the event or object stimulates the organism through a sensory-end-organ. Factors effecting this process and its completion are the size, range, and movement of the stimuli.

The most vital step is the selection and interpretation stage. Stimuli are sorted out and given meaning. Past experience is weighed with present stimuli and quantitative or qualitative value judgments are made. A decision is also made concerning how the perceiver will react to the event. Most important here is the individual's own perceptions of his capacities to handle the situation. Herein lies the foundation of the concepts of intelligence and motor coordination.

Finally, the organism must reinterpret and evaluate the decision he has made. The feedback which occurs aids in the development of future preparatory sets and to learning. (5:91-93)

Of course, many things may influence the perceptual process. Growth is a definite factor in considering the developmental level of the individual and his capacity for certain perceptions. (5:89) Motivation is involved in the attention set of an individual. One focuses upon certain events and perceives them clearly; while, other items are marginal and only dimly perceivable. Focus changes from minute to minute.

Factors involved are intensity and size, contrast, repetition, movement, motives, and set or expectancy. (15:307-309)

Man lives and moves about in space. His perception of space determines the direction of his behavior. He learns to relate between objects in their geometrical relationships to one another and himself. Vision plays a primary role in this perception giving cues to compare various objects with each other in two and three dimensional space. (5:135) This is our most sophisticated and objective sense. It ". . . simultaneously . . . [registers] . . . position, distance, size, color, and form." (7:256) Because of its importance, vision and visual perceptions have been considered definite factors in athletic performance. In the Russian studies by Krestovnikov, from experiments in ocular muscle balance, it was concluded that ". . . champion athletes have a more perfect eye-moving apparatus than non-athletes." (30:482)

STUDIES RELATED TO DEPTH PERCEPTION

The eye factor considered in this present study was depth perception. In order to better understand depth perception, one might divide its factors into two groups. First there are the primary criteria, i.e., those factors of a physiologic and innate nature--physiologic diplopia, accommodation, convergence, binocular parallax. And, second, the cues to depth which are learned through experience--size of the retinal image, motion parallax, terrestial association, and aerial perspective. (1:72-76) All of these factors combine to give the perceiving organism a picture of its three-dimensional world in a split-second's time.

In sports activity, the concern is with the depth perception of moving objects. The individual never visually perceives actual motion of objects directly. There is, in reality, a displacement of objects relative to the rest of the field. (11:282) This results in

> . . . successive stimulation of receptors leaving a trail of 'on/off' discharges which give some indication of direction and total displacement. (24:97)

It works on the eyes much like the motion picture does. The movement is perceived as radial or tangential (34:394) and the same types of cues involved in stationary depth perception are evident in movement depth perception. For instance, changing size of an object is a cue to radial motion (9:71) and spatial frameworks can determine velocities of movement and direction of apparent movement. (20:137)

The apparatus most often used as the basis for a study of depth perception is the Howard-Dolman Apparatus. It was first adapted from a piece of equipment devised by Brooksbank James, of England, in 1908. (33:659) The adaption was developed by Captain Henry J. Howard in 1919 to replace the stereoscopic tests used in the classification of applicants for the aviation service. Howard developed the test as one of binocular parallax because he saw this as a pure factor uninfluenced by experience. A study by Hess backs up this point of view. He found that, with naive Leghorn chicks, binocular depth perception required neither learning nor continued use but appeared to be an entirely innate factor. (32:80) Howard determined that a depth perception between 20 and 30 mm. was the distinguishing point between normal and abnormal depth perception. (33:688) In Howard's apparatus, the rods were manipulated by an operator. In a more recent adaption, the Howard-Dolman Apparatus, the subject aligns two rods by means of manipulating two strings. Armstrong suggests that with this apparatus a depth perception of 30 mm. should be the line between normal and abnormal depth perception. (1:78)

Results of testing to determine relationships between depth perception and sports skill vary. In a study conducted by Bannister and Blackburn (26) interpupillary distance was found to be a factor in a man's success in sports. On the basis of this study, Clarke and Warren (27) investigated the effect of interpupillary distance upon depth perception and compared the interpupillary distances and depth perception scores of athletes and an unselected group of men. Depth perception was measured by the Howard-Dolman Apparatus and interpupillary distance was measured by means of an interpupillary distance guage. Visual acuity was measured by use of the standard Snellen test.

The subjects were 456 male students at the University of Southern California. These were unselected volunteers, however, the majority were freshmen in the University. Another group of 103 men having 20/20 vision in each eye were selected for a comparison of interpupillary distance and depth perception. Thirty-nine athletes were also tested. Of the athletes, 8 were from the tennis team, 13 from the basketball team, and 18 from the baseball team.

The data from the 103 subjects showed a correlation between the interpupillary distance and the depth perception scores to be $+0.124\pm0.067$. Clarke and Warren concluded that this indicated no significant relationship between the two variables.

When comparing the depth perception of the 39 athletes and the 456 men in the unselected group, the average error of the unselected group was 30.5 ± 1.1mm. and the average error of the athletes was 29.3 ± 3.8mm. This yielded a difference of $1.2\pm$ 3.9mm.; thus, Clarke and Warren concluded that the depth perception of the group of athletes was not significantly superior to that of the unselected group.

A further conclusion casts doubt upon the reliability of the Howard-Dolman Apparatus:

> Either depth perception as measured by the test is relatively unimportant in ball games of the nature of those included, or the test does not give an accurate measure of depth perception. In either event, the application of the results of this test to practical situations may be seriously questioned. (27:487)

Olsen (36) conducted a study to determine the relationship between the psychological capacities of reaction time, depth perception, and visual span of apprehension and success in college athletics, particularly basketball, soccer, hockey, and baseball.

There were three groups of volunteers from Boston University. Each group contained 100 male students. The Athletic Group was designated by those who had earned a varsity sports letter. The Intermediate Group were those who had not earned a letter but had participated in some intermural or other recreation program. The Non-Athletic Group was those who had never participated in any athletic program in college or elsewhere.

The Howard-Dolman Apparatus was the instrument used to test depth perception. Reliability of the depth perception tests was +0.893. Olsen found the following means and standard deviations for the groups:

	M	SD
Athletic Group	18.89 mm.	13.52 mm.
Intermediate Group	20.22 mm.	10.95 mm.
Non-Athletic Group	30.84 mm.	20.69 mm.

Critical ratios and levels of significance:

	CR	LS
Athletic vs. Intermediate Group	1.33	Not significant at .02 level
Athletic vs. Non-Athletic Group	4.83	.001
Intermediate vs. Non-Athletic Group	4.53	.001

Olsen's conclusions were that the athletes and intermediates had better depth perception than the non-athletes. A significant difference was not found between athletes and intermediates in depth perception.

He also determined relationships between the depth perception scores of the athletes and their sports skill score in soccer, baseball, and hockey. The soccer test consisted of four items--distance kicks, obstacle dribble, placement kick for accuracy, and goal kick for accuracy. There were 21 varsity soccer players tested and the correlation between their skills score and depth perception score was a -0.184.

The baseball test consisted of four items--accuracy throw, distance throw, base running speed, and batting average for the season. There were 13 varsity baseball players tested and the correlation between their skills score and depth perception score was a -0.075.

The hockey skill was determined by the average number of assists and goals made per game. There were 26 varsity hockey players tested and the correlation between their skills score and depth perception score was a -0.172.

Russian studies as reported by Graybiel, Jokl, and Trapp (30) have shown more positive conclusions. In their depth perception studies, using an apparatus similar to the Howard-Dolman Apparatus, thirty tennis players were found to have much better depth perception than 122 football players. It was also determined that the sportsmen did much better in depth perception scores than untrained controls. A correlation was found between athletic efficiency of tennis and soccer players and their depth perception scores. The conclusion was that more skillful players perceived depth more accurately.

A more recent study, by Miller (13), investigated the relationship between sports skill and the ability to perceive, analyze, interpret, and react to visual cues as measured by selected tests which involve visual perception. Part of the study involved depth perception. The instrument used to measure depth perception was the Keystone Telebinocular Multi-Stereo Professional Performance Tests which stress the importance of binocularity.

The subjects for the study were men and women between the ages of 18 and 49. There were three groups: Champions, 30 men and 30 women who held Olympic, state, national, or regional ratings; Near Champions, 21 men and 21 women who were runners-up of high level status; and Low-Skilled, 30 men and 30 women who were considered untrained. The sports activities considered were volleyball, basketball, fencing, swimming-diving, and gymnastics.

In comparing the champion and low-skilled group for men and women combined, Miller found a significant difference between the means of the two groups and felt the results to indicate that the ability to perceive depth was important to the highly skilled. She agreed with Olsen (36) that ability to perceive depth is not significantly different between champions and near champions.

There were contradictory results between men and women with regard to relative importance of depth perception to specific activity. Fencing seemed most important for men with swimming, gymnastics, volleyball, and basketball following; however, for women, volleyball was first followed by gymnastics, swimming, fencing, and basketball. The relatively high placement of gymnastics may be explained by the fact that Miller also found a significant correlation between depth perception and balance.

Thus, from the studies cited, it can be seen that some definite relationship does exist between athletic success and depth perception. Athletes do seem to have better depth perception than non-athletes. Confusion develops when one tries to explain the nature of this relationship. Is the successful athlete successful because of his better depth perception? Results of correlations between depth perception and sports skills leave much unanswered. It seems that only certain skills lend themselves to a positive relationship with depth perception.

It is entirely possible that depth perception is a contributing factor in the development of an athlete, not a sustaining force behind athletic ability. In other words, depth perception makes learning a sport skill easier in the early stages of learning. Fleishman has concluded

> It would seem that initially, exteroceptive cues (spatial-visual) provide information which guides Ss' movements . . . . Once a given level of proficiency is reached and errors tend to be smaller, spatial cues are not as effective . . . . The Ss high in spatial ability have an advantage only in earlier stages of learning . . . . (28:11)

This advantage, or "edge," may be the very factor which determines who will remain unskilled and who will become a successful athlete.

CHAPTER IV

PROCEDURE

The purposes of this study were (1) to develop a standardized measure of depth perception of moving objects, (2) to determine the relationship between depth perception of moving objects and sports skill, (3) to re-explore the relationship between depth perception of stationary objects and sports skill, and (4) to compare the relative effectiveness of the two methods of measuring depth perception in relating this quality to sports skill. The procedures to accomplish these ends involved selection of the instruments to be used, a pilot study to establish the reliability of the instruments, a main study to determine relationship between depth perception and sports skill, and statistical treatment of the data to determine the results of the study.

DEPTH PERCEPTION INSTRUMENTS

Two instruments were used in this study. One was the Howard-Dolman Apparatus (1:77; 39), a traditional measure of depth perception, and the other was an adaption of the Howard-Dolman Apparatus constructed as a new measure of the depth perception of moving objects.

The Howard-Dolman Apparatus tests ability to use the binocular parallactic angle in judging depth. It is a simple box 24¼ inches long by 11½ inches wide consisting of three sides: front, back, and bottom. The apparatus is painted black. There is a piece of white cardboard placed in front of the back panel to reflect light. The front panel has an opening 7½ by 3 inches through which can be viewed two vertical rods 2¼ inches apart laterally. One rod is stationary and the other is placed on a sliding base which can be moved forward and backward by means of cords held in the examinee's hands. A scale in millimeters is arranged along the middle of the slide guide. The subject manipulates the cords until he feels the two rods are in perfect alignment.

The adaption of the Howard-Dolman Apparatus (Figure 1) tests the ability to use the binocular parallactic angle in judging depth of moving objects. It is a simple box 29 inches long by 11½ inches wide consisting of four sides and a bottom. The apparatus is painted black. There is a piece of white cardboard placed in front of the back panel to reflect light. The front panel has an opening 7½ by 3 inches through which can be viewed two vertical rods 2½ inches apart laterally. The two rods are pulled on metal rails by a battery-operated electric motor. The motor runs a countershaft speed of 600 RPM with a three-volt dry battery. Both rods move and are controlled by the means of an on-off switch. The rods are

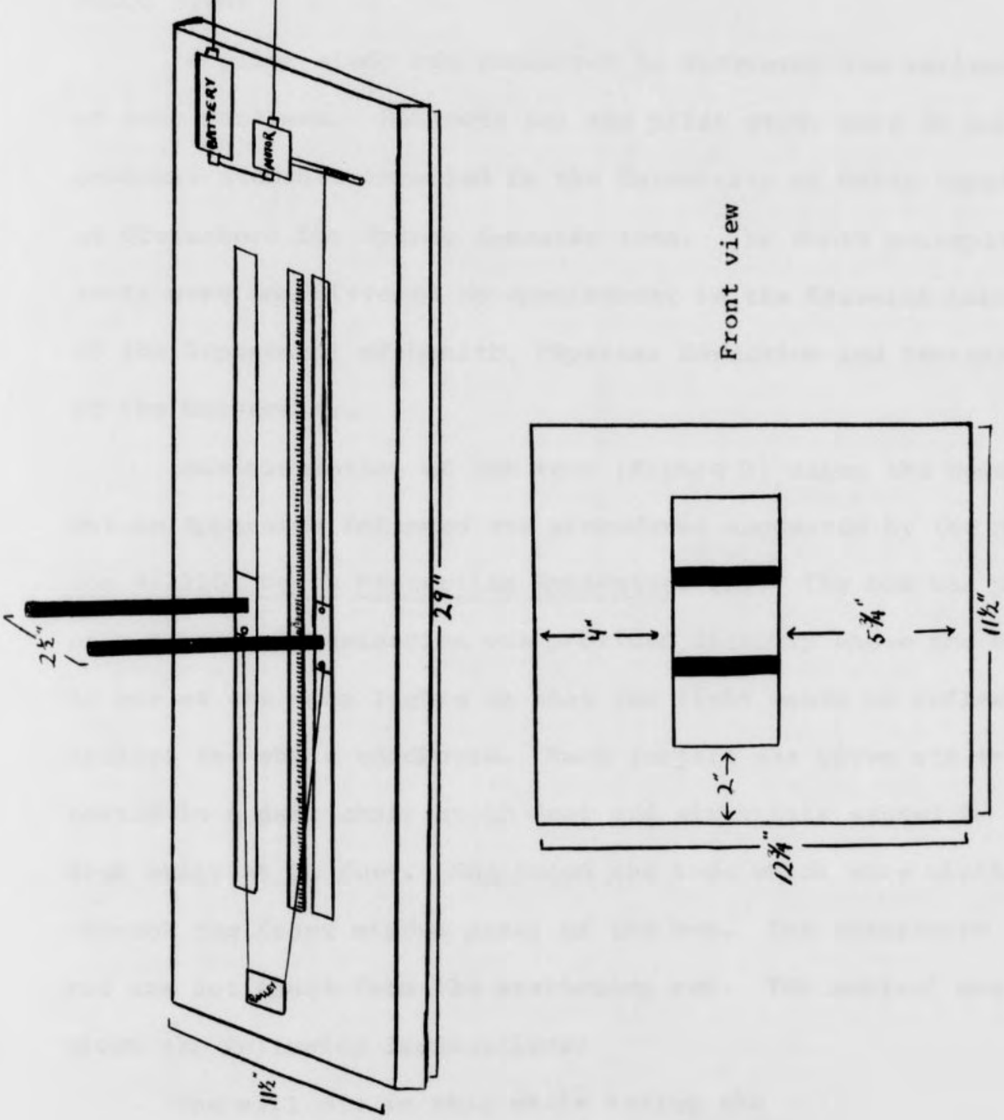

FIGURE 1

ADAPTED APPARATUS

set apart and the subject tries to align them as they move toward one another. A scale in millemeters is arranged along the middle of the slide guides.

PILOT STUDY

A pilot study was conducted to determine the reliability of both machines. Subjects for the pilot study were 30 women graduate students enrolled in the University of North Carolina at Greensboro for Spring Semester 1966. The depth perception tests were administered by appointment in the Research Laboratory of the Department of Health, Physical Education and Recreation of the University.

Administration of the test (Figure 2) using the Howard-Dolman Apparatus followed the procedures suggested by the Manual for #12220, Depth Perception Apparatus. (39) The box was placed on a table. Illumination was provided directly above the box by one of the room lights so that the light would be reflected against the white cardboard. Each subject was given six trials seated in a desk chair at 10 feet and six trials seated in a desk chair at 20 feet. She faced the rods which were visible through the front window panel of the box. The adjustable rod was set apart from the stationary rod. The subject was given the following instructions:

> You will sit in this chair facing the apparatus. There are two rods in the apparatus--one is stationary. The movable

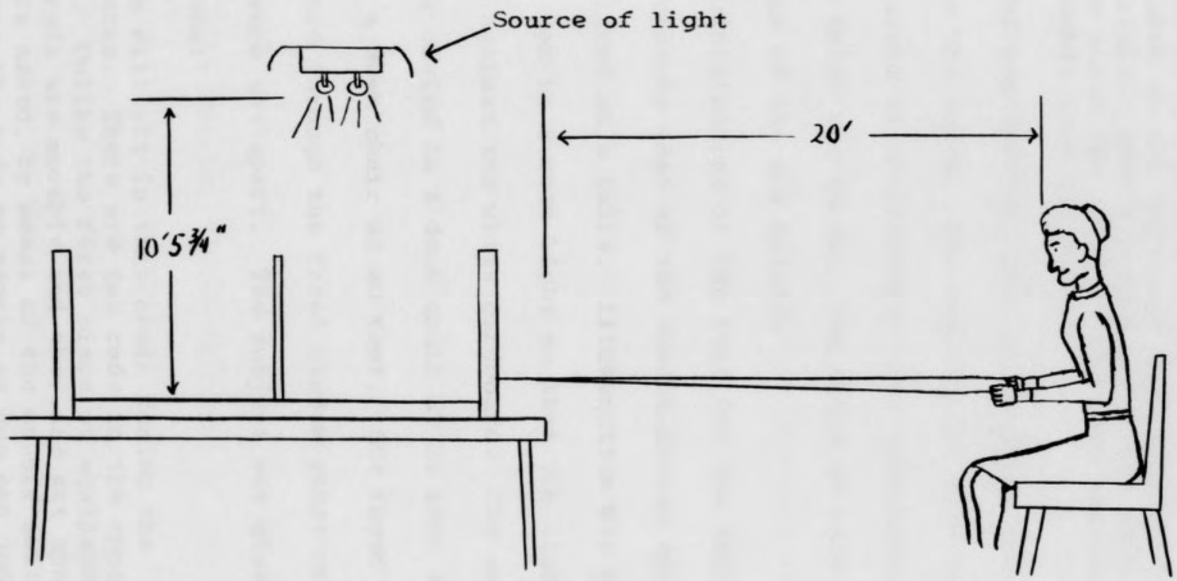

FIGURE 2

ARRANGEMENT FOR HOWARD-DOLMAN APPARATUS

> rod is set apart from the stationary one. You are asked, by means of manipulating the two cords, to place the movable rod as nearly as you can judge opposite the stationary rod or such that both are equidistant from you. You will have six trials at this distance of 10 feet and six trials at a distance of 20 feet. You are asked to not move your head or body during the trials. When you have completed each trial, please place the cords on the desk top and remove your hands from the cords.

After receiving instructions, the subject was shown how to manipulate the cords. The reading for each trial was taken from the scale in millimeters. The adjustable rod was reset and a new trial was taken. The score at each distance was the average of the six trials.

Administration of the test for the Adapted Apparatus followed closely that of the Howard-Dolman Apparatus. The box was placed on a table. Illumination was provided directly above the box by a room light so that the light would be reflected against the white cardboard. The subject was given six trials seated in a desk chair at 10 feet and six trials seated in a desk chair at 20 feet. She faced the rods which were visible through the front window panel of the box. The two rods were set apart. The subject was given the following instructions:

> You will sit in this chair facing the apparatus. There are two rods in the apparatus. Unlike the first piece of equipment, both rods are movable and they are set apart. You are asked, by means of the on-off switch, to place the rods as nearly as you can judge opposite each other or such that both are

> equidistant from you. You will have six trials at this distance of 10 feet and six trials at a distance of 20 feet. You are asked to not move your head or body during the trials. A trial begins when you switch the apparatus on; it ends when you switch the apparatus off. You may hold the switch in your hand between trials.

After reading the instructions, the testor demonstrated the use of the on-off switch and the subject was allowed to try the switch. The reading was taken on each trial from the scale in millimeters. The rods were re-set, and a new trial was taken. The score at each distance was the average of the six trials.

Reliability coefficients were computed for the Howard-Dolman Apparatus at 10 feet and 20 feet and for the Adapted Apparatus at 10 feet and 20 feet. These reliabilities were computed through use of a raw-score formula and are listed in Table I, page 30. The Adapted Apparatus at 10 feet and at 20 feet was found to be reliable with three trials, however, it was necessary to increase the number of trials to six with the Howard-Dolman Apparatus. The Spearman-Brown Prophesy Formula was used to determine the proportion of increase. The Adapted Apparatus appeared to be more reliable at each distance than the Howard-Dolman Apparatus. At 10 feet, the Adapted Apparatus had a split-halves reliability coefficient of .89 while the Howard-Dolman Apparatus with the application of the Spearman-Brown Prophesy Formula had a reliability coefficient of .82. At 20 feet, the Adapted Apparatus had a split-halves reliability coefficient of .87 while the Howard-Dolman Apparatus with the application of the Spearman-Brown Prophesy Formula had a reliability coefficient of .73.

TABLE I

RELIABILITY OF DEPTH PERCEPTION INSTRUMENTS
AS ESTABLISHED IN THE PILOT STUDY
N = 30

Instrument	Distance	Reliability Coefficient
Howard-Dolman Apparatus	10 feet	.82*
Howard-Dolman Apparatus	20 feet	.73*
Adapted Apparatus	10 feet	.89
Adapted Apparatus	20 feet	.87

*Stepped up by Spearman-Brown Prophesy Formula: Proportion of increase--2.

Only the Howard-Dolman Apparatus at 20 feet failed to meet a minimum standard of .80. (2:42) The time available for administering additional trials was limited. Both instruments were considered sufficiently reliable measures at both distances.

MAIN STUDY

When the two tests had been established as reliable measures, a study was undertaken of the relationship between depth perception as measured by these pieces of apparatus and sports skill. The subjects were 36 women physical education majors enrolled in the University of North Carolina at Greensboro for the Spring Semester 1966. They volunteered to participate in the study. The depth perception tests were administered by appointment in the Research Laboratory of the Department of Health, Physical Education and Recreation of the University.

Administration of the depth perception tests followed the same procedure used in the pilot study with one exception. Results of the pilot study showed the Adapted Apparatus to be sufficiently reliable with three trials at each distance; whereas, the Howard-Dolman Apparatus required at least six trials at each distance. This was determined by application of the Spearman-Brown Prophesy Formula. As a result, the Adapted Apparatus was administered to this group with three trials at each distance and the average of the three trials was the score for each distance.

The sports skills selected were the Lockhart-McPherson Badminton Wall Volley Test (2:269), Scott-French Softball

Repeated Throws Test (2:307), and the Scott-French Revision of the Dyer Wallboard Test (2:322). A detailed description of these tests may be found in the Appendix.

These tests were chosen because each requires that the subject make contact with a moving object. They were also chosen on the basis of ease of administration, familiarity of subject with the skills being tested, and reliability and validity.

The three skills tests were administered in one testing period. Subjects were divided into four groups. There were four stations for each test. Each group had two scorers and there was one central timer. Each test was explained and demonstrated. Subjects were rotated between trials in order to allow a rest period.

TREATMENT OF DATA

In the pilot study, the mean depth perception scores and reliability coefficients were found for two distances with the Howard-Dolman Apparatus and for two distances with the Adapted Apparatus. In the main study, the means and standard deviations were found for each instrument at each distance and the scores from the two instruments were correlated to determine if they were measuring the same thing. The scores for the depth perception instruments were also correlated with the scores from each of the three skills tests at each distance.

CHAPTER V

ANALYSIS OF DATA

PRIMARY COMPARISONS OF RELATIONSHIPS BETWEEN INSTRUMENTS

In the pilot study, the ranges, means, and standard deviations were determined for scores on both of the instruments at 10 feet and at 20 feet and may be found in Table II, page 34. It is interesting to note that the least reliable test, the Howard-Dolman Apparatus at 20 feet, had the smallest range of scores while the most reliable test, the Adapted Apparatus at 20 feet, had the largest range of scores. The manual for operation of the Howard-Dolman Apparatus reports that the average depth perception of persons, regardless of vision, at 20 feet was found to be 18.6 mm. (39) with both eyes. In this pilot study, the mean depth perception for persons, regardless of vision, at 20 feet was 35.30 mm. The Adapted Apparatus at both distances had a lower mean score and a smaller standard deviation.

In the main study, the ranges, means, and standard deviations were determined for scores on both the instruments at 10 feet and at 20 feet and may be found in Table III, page 35. In this study, the least reliable test, the Howard-Dolman at 20 feet, again showed a greater range between scores. As in the pilot study, the mean depth perception at 20 feet on

TABLE II

RANGE OF SCORES, MEANS, AND STANDARD DEVIATIONS FOR DEPTH PERCEPTION INSTRUMENTS IN PILOT STUDY
N = 30

Instrument	Distance	Range	Mean	S. D.
Howard-Dolman Apparatus	10 feet	6-82 mm.	17.53 mm.	16.50 mm.
Howard-Dolman Apparatus	20 feet	7-79 mm.	35.30 mm.	19.82 mm.
Adapted Apparatus	10 feet	3-87 mm.	12.23 mm.	15.03 mm.
Adapted Apparatus	20 feet	6-91 mm.	28.43 mm.	19.67 mm.

TABLE III

RANGE OF SCORES, MEANS, AND STANDARD DEVIATIONS FOR DEPTH PERCEPTION INSTRUMENTS IN MAIN STUDY
N = 36

Instrument	Distance	Range	Mean	S. D.
Howard-Dolman Apparatus	10 feet	3-50 mm.	13.42 mm.	9.28 mm.
Howard-Dolman Apparatus	20 feet	5-113 mm.	35.5 mm.	24.42 mm.
Adapted Apparatus	10 feet	2-78 mm.	12.78 mm.	14.08 mm.
Adapted Apparatus	20 feet	3-70 mm.	22.44 mm.	16.05 mm.

the Howard-Dolman Apparatus exceeded that reported by the manual for operation. (39) In this study, the mean depth perception at 20 feet with the Howard-Dolman Apparatus was 35.5 mm. while the manual reports a mean depth perception with the same instrument at 20 feet of 18.6 mm. The Adapted Apparatus at both distances had a lower mean score, however, there was no pattern for the standard deviations.

Very low correlations were found between the two depth perception instruments. (Table IV, page 37) At 10 feet, there was no significant relationship between the two instruments and, therefore, it appears that they are not measuring the same thing. At 20 feet, the relationship between the instruments was found to be low but significant at the .05 level of confidence.

RELATIONSHIPS BETWEEN DEPTH PERCEPTION TESTS AND SKILLS TESTS

The ranges, means, and standard deviations were determined for scores on the three skills tests and may be found in Table V, page 38. The scores appeared to be normally disturbed for each of the skills tests.

Using the raw data formula, correlations were also determined between the depth perception instruments at both distances and the three sports skills tests. These correlations are reported in Table VI, page 39. A coefficient of .32 would be necessary to be significant at the five per cent level of confidence. There seems to have been no relationship between the softball repeated throws test and depth perception as measured by either instrument for these 36 girls. These results do seem

TABLE IV

CORRELATION COEFFICIENTS BETWEEN DEPTH PERCEPTION TESTS
N = 36

Depth Perception Tests	r
Howard-Dolman Apparatus and Adapted Apparatus at 10 feet	.04
Howard-Dolman Apparatus and Adapted Apparatus at 20 feet	.39*

*r = .32 necessary to be significant at the .05 level of confidence.

TABLE V

RANGE OF SCORES, MEANS, AND STANDARD DEVIATIONS
FOR SKILLS TESTS
N = 36

Test	Range	Mean	S. D.
Softball Repeated Throws	59-127	96	16
Badminton Wall Volley	31-107	61	19
Tennis Wall Volley	17-44	29	7

TABLE VI

CORRELATION COEFFICIENTS BETWEEN DEPTH PERCEPTION TESTS AND SPORTS SKILLS*
N = 36

Skills Tests	10 feet		20 feet	
	Howard-Dolman	Adapted	Howard-Dolman	Adapted
Softball				
Repeated throws	-.01	-.01	-.002	.02
Badminton				
Wall volley	.07	-.06	-.06	-.04
Tennis				
Wall volley	.04	.19	.04	.09

*r = .32 necessary to be significant at the 5 per cent level of confidence.

to coincide with those of Olsen (36) who found no significant relationship between depth perception and baseball skill.

The badminton and tennis wall volley tests scores also do not correlate significantly with the two depth perception measures. It is interesting to note that in the studies by Olsen (36) and Miller (13) no significant relationship was found between depth perception and the sports skills tested. Though the skills tested in this study have not been used in previous depth perception studies, the results do seem to agree with other studies that there is no relationship between depth perception and sport skill.

For an explanation of the lack of correlation, reference might be made to Flieshman's conclusion that exteroceptive cues such as depth perception are only an advantage in earlier stages of learning. In other studies (13; 36) comparing athletes and non-athletes, the athletes have been shown to have superior depth perception. In these same studies, the depth perception of athletes has not been shown to correlate significantly with the scores of athletes on sports skills. It would appear that, on the basis of previous studies and the current study, depth perception is a contributing factor in the development of an athlete, not a sustaining force behind athletic ability.

A superficial examination of the coefficients to compare the instruments seems to indicate that no pattern exists between them. It is not possible to state from these data that one instrument is superior to the other in its relationship to sports skill.

CHAPTER VI

SUMMARY AND CONCLUSIONS

This study sought to develop a standardized measure of depth perception of moving objects, to determine the relationship between depth perception of moving objects and sports skill, to re-explore the relationship between depth perception of stationary objects and sports skill, and to compare the relative effectiveness of the two pieces of apparatus in relating depth perception to sports skill.

The following conclusions were drawn on the basis of the performance of the subjects:

1. The Howard-Dolman Apparatus at a distance of 20 feet had a low reliability coefficient. The Howard-Dolman Apparatus at a distance of 10 feet and the Adapted Apparatus at both distances proved to be sufficiently reliable.
2. The Adapted Apparatus, which involved moving objects, showed a low relationship to the Howard-Dolman Apparatus at 20 feet. The relationship of .39 was high enough to be significant but not substantial to any great extent.

3. The Howard-Dolman Apparatus showed no relationship to the softball repeated throws, badminton wall volley, or tennis wall volley tests.
4. The Adapted Apparatus showed no relationship to the softball repeated throws, badminton wall volley, or tennis wall volley tests.
5. From the data collected, it was concluded that while the Adapted Apparatus, which involves moving objects, appeared to be a reliable measure it did not appear to be any more accurate a measure than the Howard-Dolman Apparatus. It was shown, however, to require fewer trials to be administered.

SUGGESTIONS FOR FURTHER STUDY

1. Because the Adapted Apparatus was a home-made construct, it is possible that scores were not accurately measured. A study using a more finely constructed instrument is suggested.
2. Scores on both depth perception instruments were recorded as whole numbers describing the distance in millimeters from 0, the point at which both rods were equidistant from one another. No consideration was made of the placement of the rods in relation to one another. It is possible than an

individual who was consistently behind or ahead of the 0 point might also be a consistent late or early swinger in sports involving the use of a bat or racket.

3. The subjects used in the main study were physical education majors. No differentiation in skill level was made. A study using these same instruments and skills tests with a larger number of subjects classified as to skill level might yield more conclusive results.
4. In trying to develop a more life-like situation for the subjects, the distances traveled by the rods might be enlarged to more nearly approximate those distances encountered in sports activities.
5. Other sports skills might be correlated with depth perception to determine if any pattern of relationship exists.

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APPENDIX

COPY OF LETTER SENT TO SUBJECTS

Dear ________________,

Thank you for participating in my thesis study on the relationship between depth perception of moving objects and sports skill. As you know, you have finished the section on depth perception and, now, you are scheduled to take the skills tests on Thursday, April 14 from 7-9 p.m. Will you please fill out the form below and return it to my box in Coleman gymnasium by Wednesday, April 13.

Remember to wear your gym uniform and, please, bring your own tennis racket. If you wore glasses to take the depth perception tests, you must wear them for the skills tests.

Thanks again. See you Thursday night.

______ I will come Thursday night, April 14.

______ I would like to come Monday night, April 18.

______ I must schedule a time other than Thursday or Monday.

NAME______________________________

SKILLS TESTS DESCRIPTIONS

I. LOCKHART-MCPHERSON BADMINTON WALL VOLLEY TEST (2:269-279)

Evaluation: Reliability .90 Validity .71.

Facilities and Equipment: Badminton racket, shuttlecocks, wall space 10 feet high and 10 feet wide, stop watch, floor space 10 feet wide and 10 feet in depth from the wall.

Procedure: The player stands behind the 6½-foot line holding a racket and shuttlecock. On signal, she executes a legal badminton serve against the wall above the 5-foot net line. After the serve the player may play the shuttlecock from anywhere behind the 3-foot restraining line. The shuttlecock may remain in play when hit from inside the 3-foot area or if it hits below the 5-foot net line but the point does not score. The volley may be restarted whenever necessary from the 6½-foot line with a legal serve. The serves do not count as points. All other legal hits against the wall score 1 point. A 15-second practice trial is permitted followed by three 30-second trials which are recorded and which are interspersed with rest periods.

II. SOFTBALL REPEATED THROWS TEST (2:308-309)

Evaluation: Reliability .94.

Facilities and Equipment: A wall space about 15 feet high and 10 feet wide, balls, stop watch.

Procedure: The student stands behind the 15-foot restraining line and throws the ball repeatedly at the wall above the 7½-foot mark. Only one ball may be used during the test. The student may go ahead of the line to recover a ball but must be behind it for the throw to count. A 2-minute rest period between each of the six trials is recommended. Score 1 point for every hit against the wall which lands on or above the 7½-foot mark and which is released from behind the 15-foot line. The final score is the total number of hits for six trials.

III. SCOTT-FRENCH REVISION OF THE DYER WALLBOARD TEST (2:322-324)

Evaluation: Reliability .80. Validity .61.

Facilities and Equipment: Two rackets, 10 to 12 balls, wall and floor space, the net line should be 3 inches in width and should be included in the 3-foot distance.

Procedure: The player stands behind the restraining line holding a racket and 2 balls. The ball is put into play by bouncing it and stroking it against the wall. The rally continues for 30 seconds, using any stroke desired. If the ball gets out of control, another one is started in the same manner in which the test was started. Balls hit short of the restraining line or which land below the 3-foot mark do not score but sometimes help to keep the rally going. After the initial bounce to start the rally, the ball may be hit on the volley or after any number of bounces. The player should get 2 more tennis balls from the racket face whenever they are needed to keep the rally going. Three 30-second trials are given. The score is the total hits for all three trials. A legal hit must land above the 3-foot line on the wall and must be contacted from behind the 27½-foot restraining line.

No. _______ Name ____________________________ Date ________

REPEATED THROWS TEST	BADMINTON VOLLEY	TENNIS VOLLEY
TRIALS:	TRIALS:	TRIALS:
1. ________	1. ________	1. ________
2. ________	2. ________	2. ________
3. ________	3. ________	3. ________
4. ________	TOTAL: ________	TOTAL: ________
5. ________	T-SCORE: ________	T-SCORE: ________
6. ________		
TOTAL: ________		
T-SCORE: ________		

FIGURE 3

SAMPLE SCORE CARD

TABLE VII

RAW SCORES FROM DEPTH PERCEPTION TESTS
IN MAIN STUDY

Subject	Howard-Dolman Apparatus		Adapted Apparatus	
	10 feet	20 feet	10 feet	20 feet
1.	5	24	9	13
2.	4	10	4	6
3.	6	16	4	23
4.	22	58	15	51
5.	15	21	7	18
6.	17	55	19	11
7.	10	18	3	10
8.	4	11	5	14
9.	3	6	9	12
10.	28	56	8	10
11.	9	19	13	8
12.	7	17	15	31
13.	6	75	78	70
14.	21	46	23	9
15.	27	113	54	44
16.	12	10	14	36
17.	9	46	2	5
18.	22	47	15	15
19.	7	12	12	9
20.	15	37	6	10
21.	17	24	9	29
22.	10	31	12	34
23.	3	5	13	42
24.	14	40	7	13
25.	9	50	9	29
26.	16	67	8	52
27.	10	44	13	3
28.	28	79	13	37
29.	50	66	4	22
30.	16	16	7	11
31.	16	23	7	11
32.	6	22	16	8
33.	6	35	14	20
34.	12	53	7	27
35.	13	17	3	17
36.	8	9	3	48

TABLE VIII

RAW SCORES FROM SKILLS TESTS

Subject	Softball	Badminton	Tennis
1.	125	107	44
2.	110	62	22
3.	93	40	20
4.	115	85	34
5.	86	42	21
6.	99	65	33
7.	70	31	31
8.	127	65	44
9.	100	95	39
10.	104	43	28
11.	86	39	23
12.	118	87	42
13.	91	59	17
14.	111	54	24
15.	94	56	28
16.	96	39	38
17.	108	61	34
18.	87	67	30
19.	108	105	38
20.	93	65	27
21.	82	42	27
22.	97	75	31
23.	95	72	26
24.	66	74	25
25.	89	71	25
26.	97	68	36
27.	92	43	30
28.	112	70	40
29.	113	74	28
30.	74	33	18
31.	108	66	30
32.	127	65	31
33.	79	60	25
34.	59	53	22
35.	90	39	23
36.	72	36	20